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This handbook for the port of La Maddalena, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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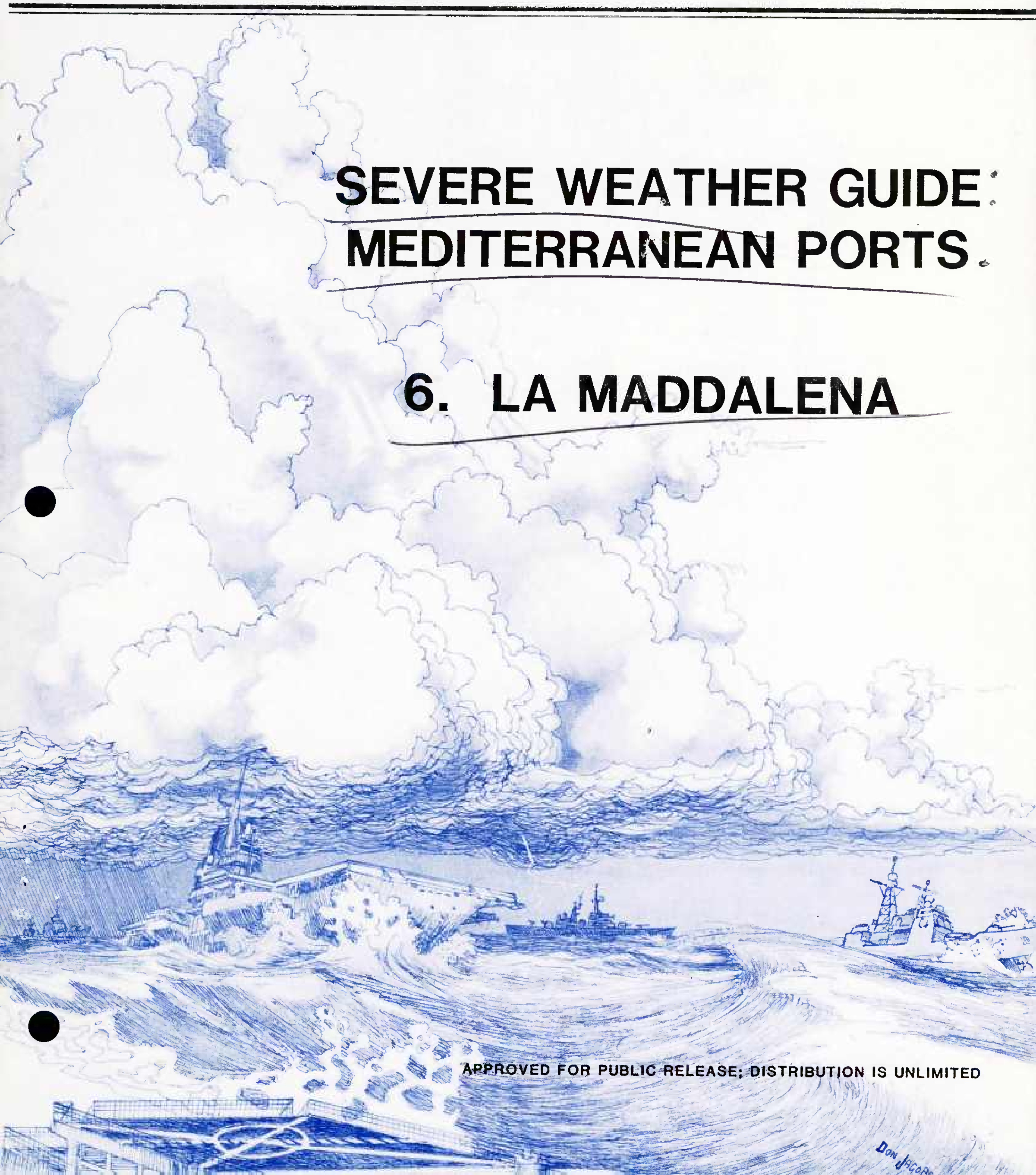
SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

6. LA MADDALENA



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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The La Maddalena Island Group is centered near 41.2°N, 9.4°E off the northeast end of Sardinia. It is about 210 n mi west of the Port of Gaeta, Italy (Figure 2-1).

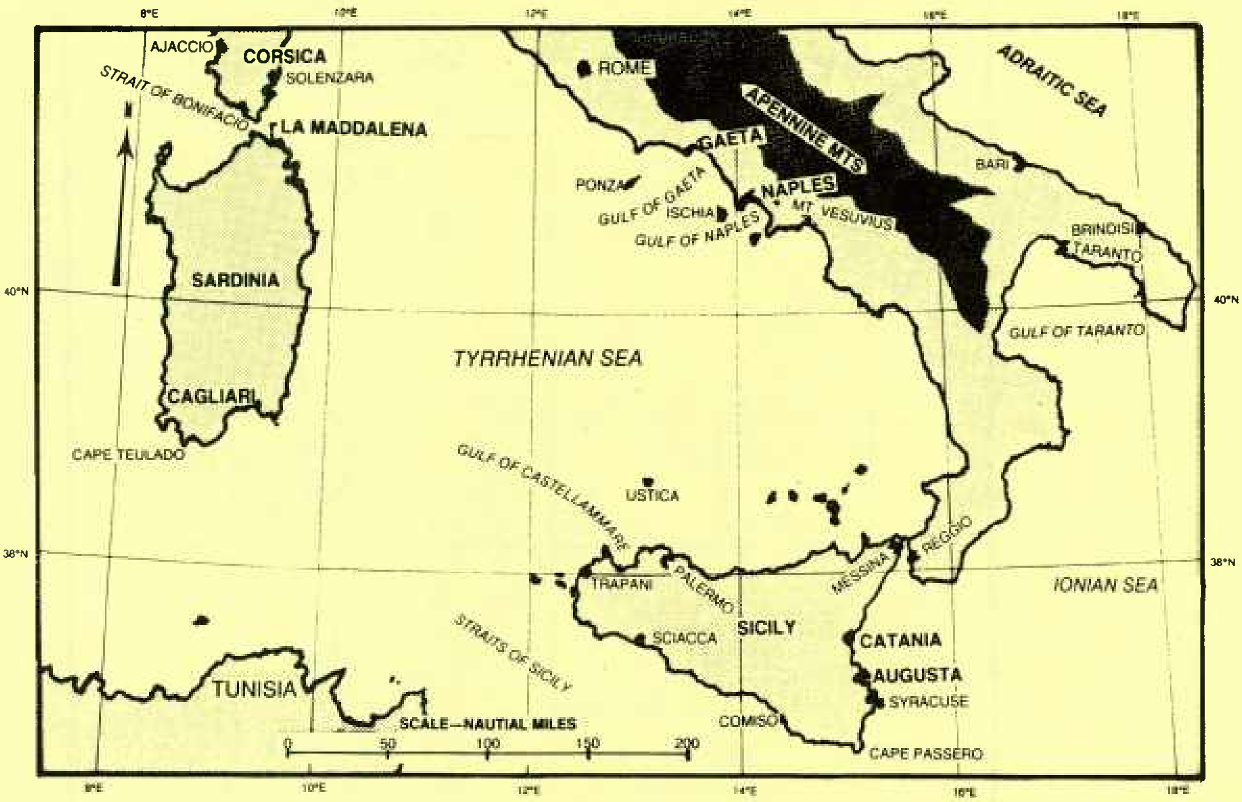

Figure 2-1. Ports of Italy, Sicily, and Sardinia.

The <u>La Maddalena Port Complex</u> is about 10 n mi southeast of the center of the Strait of Bonifacio and 15 n mi (direct line) northwest of the Gulf of Aranci (Figure 2-2). Winds and resulting wave conditions are strongly influenced by local effects, and are not representative of the open sea conditions.

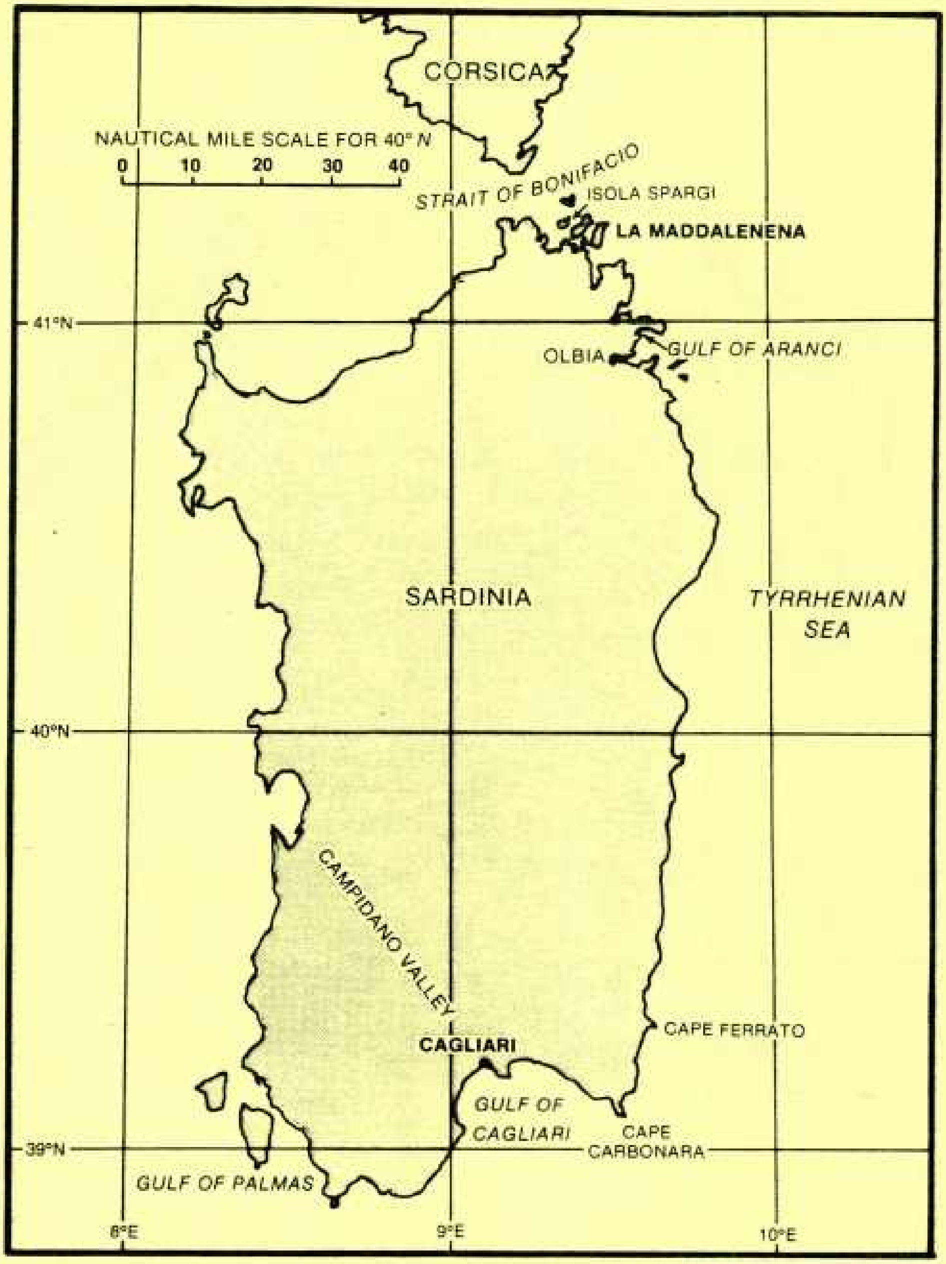

Figure 2-2. La Maddalena Island Complex

The port facilities of interest in this study in the La Maddalena complex include the Submarine Tender Mooring on the east coast of Isola Santo Stefano, the Fleet Landing on Isola La Maddalena, and Palau City Pier on the north coast of Sardinia (Figure 2-3).

It is important to note that according to local mariners, THE PREVAILING WIND DIRECTION AT SEA CANNOT BE ASSUMED TO REPRESENT THAT WHICH WILL BE ENCOUNTERED IN THE LA MADDALENA ISLAND GROUP.

The submarine tender site is vulnerable to strong northeasterly winds and seas which funnel through the passage between Isola La Maddalena and Isola Caprera. When winds are west or northwesterly (called 'Ponente') the lee area, where the site is located, is subjected to swirling winds with changeable direction at low levels. This makes berthing and helicopter operations difficult, if not unsafe.

The Palau city pier is adversely affected by northwesterly swell, generated by Mistral/Ponente conditions. Small boat operations to Palau are curtailed during a strong event due to the danger of smashing against the pier structure. Commercial ferries from La Maddalena to Palau may continue to operate; however, in strong wind conditions they divert course through Radi di Santo Stefano instead of sailing directly to Palau.

The Fleet Landing on Isola La Maddalena is well protected from heavy wind and sea conditions. Anchorages in nearby waters are limited due to the presence of submarine cables, but the waters south of the town of La Maddalena are said to offer an anchorage on a bottom with good holding qualities. Volume II of the Mediterranean Pilot, states that anchorage in Rada di Santo Stefano "can be obtained by large vessels, in depths of from 18 to 23 fathoms (32 m to 42 m), sand and weed, but the holding ground is not good, and strong westerly winds sometimes cause vessels to drag. The anchorage is secure during northeasterly and southeasterly winds." A number

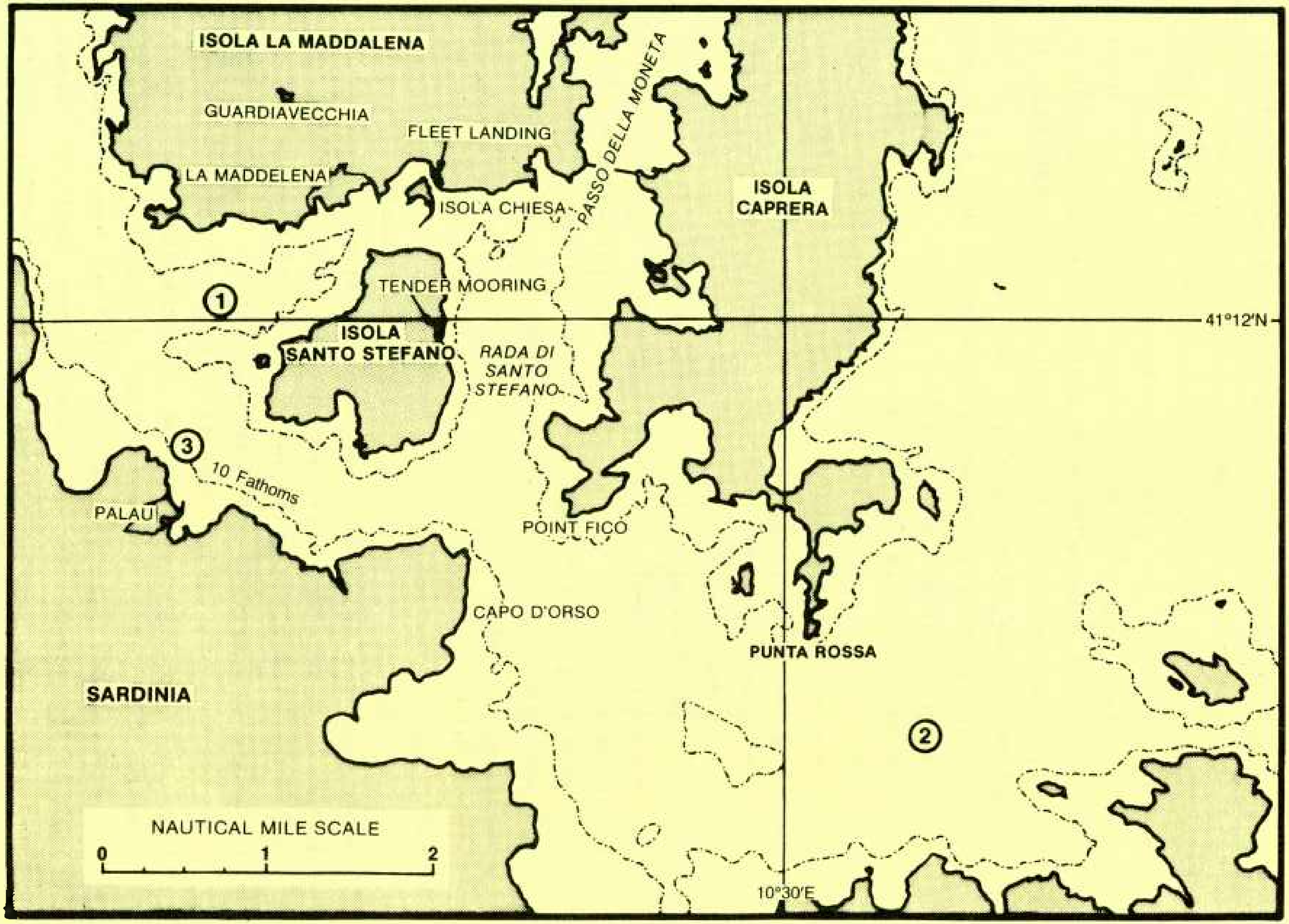

Figure 2-3. La Maddalena Port Complex

of mooring buoys, for use by Italian naval vessels, are positioned just east of the NATO pier. The NATO pier and the submarine tender on Isola Santo Stefano are protected from winds from 190° to 330° (true). These sites are most vulnerable to northeasterly winds which funnel through Paso della Moneta (Moneta Pass) between Isola La Maddalena and Isola Caprera. Winds from all other directions are diminished by the surrounding topography, with westerly winds of 30 kt often being reduced to 8-15 kt in the NATO pier area. Because of the configuration of the surrounding area, wind directions sometime vary greatly over a short distance. An example of the variability in wind direction occurs when the Ensign and Jack of the tender stand straight out, but in <u>OPPOSITE DIRECTIONS</u>. U.S. Navy aircraft carriers and other large vessels anchor southeast of Isola Caprera.

Three anchorage areas have been selected for detailed wave analysis for La Maddalena (Figure 2-3). <u>Point 1</u> is along the Fleet Landing to Palau route, just west of Isola Santo Stefano. <u>Point 2</u> is southeast of Isola Caprera where fleet vessels can anchor. <u>Point 3</u> is off the Palau City pier. There is no significant swell energy propagated into the vicinity of the submarine tender site.

Currents in Rada di Santo Stefano are generally light, with the current off the NATO pier having a southeasterly set. Persistent strong winds will enhance the currents in the area. A strong Mistral can cause a 3.5 to 4 kt easterly flowing current in the Strait of Bonifacio.

Specific <u>hazardous</u> environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios are summarized in <u>Table 2-1</u>. Use of this table can be made by entering with a known or planned vessel location/situation or an observed indicator of potential hazard and obtaining information on the specific hazard and suggested precautionary/evasive actions.

TABLE 2-1. Summary of hazardous environmental conditions for the Port of La Maddalena, Italy.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. Strong NE winds - Caused by steep pressure gradient when low pressure system is moving through Gulf of Genoa and SE across Tyrrhenian Sea. * Most likely in late autumn, winter, or early spring. * Strongest in late winter and early spring. * Uncommon in summer.	Advance warning * Strong low pressure center forecast to move through or intensify in the Gulf of Genoa and move SE across the Tyrrhenian Sea. * NW winds can veer to NE within 24 hours. Duration * Usually about 24-36 hours after onset.	(1) Submarine tender Med-moored at NATO pier on Isola Santo Stefano - submarines and/or other vessels nested alongside.	(a) Waves may wash over submarine hulls and enter open access hatches. * Submarines should be nested in lee of tender to reduce wave effect. * Close all hatches not required to be open. (b) Nested vessels may shift if exposed to full force of wind. * Submarines should be nested in lee of tender to reduce wind effect. * Mooring lines should be checked and doubled if shifting is evident.
		(2) Anchored in Rada di Santo Stefano.	(a) Vessels at anchor. * Two anchors may be required. * Move to lee of Isola Caprera to avoid worst of wind/waves.
		(3) Arriving/departing La Maddalena Island group.	(a) The prevailing wind at sea cannot be assumed to be representative of winds that will be experienced in the La Maddalena Island. The reverse is also true. * Vessels inbound to NATO pier should consider remaining at sea until NE winds subside.
		(4) Small boat operations.	(a) Small craft may experience adverse operating conditions, but boats 50-ft or larger should be able to continue normal operations.
		(5) Helicopter operations at NATO pier.	(a) Helicopter operations should be conducted with caution due to atmospheric turbulence induced by strong winds flowing over/around the surrounding rugged island region.
2. Ponente winds - Strong W to NW winds occurring when Mistral blows across western Mediterranean Sea to Strait of Bonifacio. * Strongest in winter and spring. * Uncommon, but possible, in summer. * Strong event can generate 15-20 ft waves in Strait of Bonifacio and 8-10 ft waves at Palau city pier. * Creates hazardous mooring conditions at NATO pier on Isola Santo Stefano. * Creates turbulent atmosphere for helicopter operations at NATO pier site.	Advance warning * Dark stratocumulus clouds building along west coast of Corsica when La Maddalena is clear provides 24 hour warning. * Failure of fishing boats to depart on schedule provides evidence of a possible Ponente. Duration * Generally 3-6 days, increasing in strength the first few days, then gradually diminishing. * When a W wind begins to veer to N, the wind will normally calm locally in approximately 6-10 hours.	(1) Submarine tender Med-moored at NATO pier on Isola Santo Stefano - submarines and/or other vessels nested alongside.	(a) Reduced wind speeds in lee of Isola Santo Stefano. (b) Wind direction is uncertain due to swirling winds in lee of island. * Ensign and jack may stand straight out IN OPPOSITE DIRECTIONS. * Mooring tender in Med-moored position is difficult. Smoke flares are used to determine wind direction(s) during evolution.
		(2) Anchored in Rada di Santo Stefano.	(a) Vessel location in lee of Isola Santo Stefano results in reduced wind speeds. * Wind direction is uncertain due to swirling winds in lee of island. * Deploy two anchors if strong Ponente winds are forecast.
		(3) Anchored southeast of Isola Caprera.	(a) Anchorage position provides little protection from Ponente winds. * Consider move to Gulf of Aranci on NE coast of Sardinia.
		(4) Arriving/departing La Maddalena Island group.	(a) The prevailing wind at sea cannot be assumed to be representative of winds that will be experienced in the La Maddalena Island group. The reverse is also true. * Wind conditions in the lee of island will likely vary considerably from those encountered in exposed areas between the islands. * Inbound vessels, consider remaining at sea until Ponente winds abate. * Mistral/Ponente winds can cause a 3 1/2-4 kt easterly current in the strait of Bonifacio.
		(5) Small boat operations.	(a) The W to NW Ponente winds will cause few problems directly, but the waves generated by the winds have a major impact.
		(6) Helicopter operations at NATO pier.	(a) Helicopter operations should be conducted with caution due to atmospheric turbulence induced by strong winds. * Frequent eddy over helicopter landing area adjacent to NATO pier.

TABLE 2-1. (Continued)

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
3. NW'ly waves - Caused by Mistral/Ponente winds. * 8-10 ft waves at Palau city pier disrupts scheduled boat runs. * Swell propagates south of Isola Spargi into the area west of Isola Santo Stefano. Wind waves extend beyond to the south of Stefano and Caprera causing problems for submarines and small surface units inbound to Rada di Santo Stefano.	Advance warning * To be expected anytime a Mistral is occurring in the western Mediterranean Sea or a Ponente is forecast at La Maddalena. * Swell can be expected at La Maddalena about 12-18 hours after a strong Mistral begins in the Gulf of Lion. Wave height * The wave height south of Isola Spargi and west of Isola Santo Stefano will be roughly one-half that experienced in the Strait of Bonifacio. Duration * When the wind at La Maddalena starts to veer to the N, the waves will normally calm locally in approximately 6-10 hours.	(1) Anchored southeast of Isola Caprera.	(a) Waves will develop south of Isola Caprera. * Vessels should consider moving to Gulf of Aranci on NE coast of Sardinia if waves at the anchorage become a problem.
		(2) Arriving/departing La Maddalena Island group.	(a) Sea state varies greatly with location. * Westerly winds of 15 kt or greater will produce 4-6 ft (1.2 to 1.6 m) or higher waves in the passage from the Strait of Bonifacio, south of Isola Spargi, and west of Isola Santo Stefano. Units passing E of Isola Caprera enroute to an approach from the northwest to La Maddalena can be mislead by the calm area in the lee of Caprera, only to be confronted by large waves in the Strait of Bonifacio. * Sustained NW winds of 15 kt or greater create waves in the open area E of Isola Caprera of from 10-15 ft (3 to 4.5 m). * A calm area sometimes exists E of Capo d'Orso in lee of Caprera. This can be misleading as to the existing sea state E of Caprera. * When the wind calms, the local wave conditions in the roadstead abate rapidly, but remain for an extended period of time in the approaches to the roadstead.
		(3) Small boat operations.	(a) Little impact on small boats except on runs to Palau city pier. * 8-10 ft (2.5 to 3 m) waves make docking at Palau dangerous due to danger of smashing against the pier. * Small boat runs to Palau may be curtailed in favor of larger commercial ferry service from La Maddalena.
4. Tropical cyclones - Although uncommon, tropical cyclones have been observed in the Mediterranean basin. * Most likely in late summer/autumn but may occur in any season. * Storm track is difficult to forecast accurately. Mariners must give wide berth to forecast track.	Advance warning * High, thin clouds in cyclonically spiralling bands, gradually thickening. * Long-period swell from southern semicircle with no other reasonable explanation.	(1) Submarine tender Med-moored at NATO pier on Isola Santo Stefano - submarines and/or other vessels nested alongside.	(a) Vessels should put to sea and evade storm.
		(2) Anchored in Rada di Santo Stefano.	(a) Vessels should put to sea and evade storm.
		(3) Anchored southeast of Isola Caprera.	(a) Vessels should put to sea and evade storm.
		(4) Arriving/departing La Maddalena Island group.	(a) Inbound/outbound vessels should stay at sea/go to sea and evade storm. * If at sea, stay at sea. * If departing harbor, plan to leave early.
		(5) Small boat operations.	(a) Cancel small boat operations. * Hoist small craft out of water and secure on deck or, in the case of shore-based boats, secure well above the high tide line.
		(6) Helicopter operations at NATO pier.	(a) Operate helicopters with caution. * Delay all unnecessary flights until winds abate.

Table 2-2 provides the height ratio and direction of shallow water waves to expect at points 1, 2, and 3 (Figure 2-3) when the deep water wave conditions are known.

The La Maddalena Point 2 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height (6 ft) by the ratio of shallow to deep height (.5).

Example: Use of Table 2-2 for La Maddalena Point 2.
Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:
6 feet, 12 seconds, from 060°.
The expected wave condition at La Maddalena Point 2 as determined from Table 2-2:
3 feet, 12 seconds, from 040°.

NOTE: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

LA MADDALENA POINT 1 (West of Isola Santo Stefano)

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	270°	255°	245°	265°	270°	260°
	.1	.1	.1	.2	.2	.2
270°	270°	260°	250°	260°	265°	270°
	.3	.3	.2	.2	.2	.2
300°	275°	255°	250°	245°	240°	240°
	.4	.4	.4	.5	.4	.3
330°	275°	275°	275°	270°	265°	250°
	.4	.4	.3	.3	.3	.3

LA MADDALENA POINT 2 (Southeast of Isola Caprera):

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	010°	010°	010°	010°	020°	020°
	.3	.6	.5	.5	.4	.3
030°	030°	040°	045°	025°	025°	045°
	.5	.5	.5	.4	.4	.3
060°	050°	050°	040°	040°	030°	030°
	.3	.2	.4	.5	.4	.2
090°	045°	045°	040°	040°	040°	040°
	.2	.2	.3	.3	.3	.2
120°	045°	045°	040°	040°	040°	040°
	.1	.1	.2	.2	.2	.1

LA MADDALENA POINT 3 (off Palau City pier):

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	340°	345°	355°	360°	360°	010°
	.1	.1	.1	.1	.1	.1
270°	340°	345°	355°	360°	360°	010°
	.3	.3	.3	.3	.3	.1
300°	340°	345°	355°	360°	360°	010°
	.4	.4	.3	.4	.3	.3
330°	335°	345°	350°	355°	360°	010°
	.2	.2	.2	.2	.2	.2

The local wind generated wave conditions for selected areas are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

There are at least three locations/situations in the La Maddalena complex in which wind waves can create hazardous conditions; submarines with open hatches along side the tender, ferry/liberty boat transits between the Fleet Landing and Palau, and at the anchorage site south of Isola Caprera. The significant wave height information for the three locations/situations are provided in Table 2-3.

Individual wind waves of 2 ft at the submarine tender site can be hazardous to tendered submarines with open hatches. The 5% greatest wave heights are about 2.2 times the significant wave heights.

Table 2-3. La Maddalena. Local wind waves for fetch limited conditions near the submarine tender site (3 n mi fetch), along the ferry route from the Fleet Landing to Palau (13 n mi fetch), and south of Isola Santo Stefano (5 n mi fetch) (based on JONSWAP model).

<u>Format:</u> height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
NNE 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
WNW 13 n mi	2-3/4 2	3-4/4 2-3	4/4-5 2	5/5 2	6/5 2
W 5 n mi	<2 ft	2/3 1	2-3/3-4 1	3/3-4 1	3-4/3-4 1

<u>Example:</u>
To the west-northwest (300°) there is about a 13 n mi fetch. Given a west-northwest wind at 24 kt, the sea will have reached 3-4 feet with a period of 4 seconds within 2-3 hours. <u>Wind waves</u> will not grow beyond this condition <u>unless</u> the wind speed increases or the direction changes to one with a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Combined Wave heights are obtained by finding the square root of the sum of the squares of the swell and wind wave heights.

Example: Swell 10 ft, wind wave 5 ft.

$$\sqrt{10^2 + 5^2} = \sqrt{100 + 25} = \sqrt{125} \approx 11.2 \text{ ft}$$

Note: Increase over larger height is small. If both heights were equal, combined height would increase by a factor of 1.4. If one is half of the other, as in the example, increase over the larger of the two is by a factor of 1.12.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 feet and greater than 6.6 feet.

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

LA MADDALENA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	21	12	18	18
Average Duration (hrs)	18	14	20	19
Period Max Energy (sec)	10	9	9-10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	1	1	2
Average Duration (hrs)	14	18	18	21
Period Max Energy (sec)	12	12	12	12

LA MADDALENA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	2	2	4
Average Duration (hrs)	21	6	8	10
Period Max Energy (sec)	9	9-11	9-10	9-10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	1	<1	0
Average Duration (hrs)	10	6	6	NA
Period Max Energy (sec)	10-11	10	11	NA

LA MADDALENA POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	7	11	14
Average Duration (hrs)	15	13	15	19
Period Max Energy (sec)	11	10	10	10-11
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	1	1	1
Average Duration (hrs)	13	9	19	10
Period Max Energy (sec)	12	12	12	12

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

NOTE: The prevailing wind direction at sea cannot be assumed to represent that which will be encountered in the La Maddalena Island group. The mooring or berthing of the submarine tender is difficult because of the uncertain wind direction and it has become common practice to use smoke flares to determine wind direction during berthing operations.

WINTER (November thru February):

* Northeasterlies are funneled between islands causing the above described problems at the NATO pier.
* West to northwest winds (Poniente) can last 3 to 6 days and generate 20 ft (6 m) waves in Strait of Bonifacio and 10 ft swell off Palau.

SPRING (March thru May):

* Both the strong northeasterlies and the Poniente can occur but become less frequent in late spring.

SUMMER (June thru September):

* Relatively event free.

AUTUMN (October):

* Short transition season with winter weather returning by month's end.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

Hydrographer of the Navy, 1965: Mediterranean Pilot, Volume II. Hydrographer of the Navy, London, England.

The La Maddalena Port Complex is about 10 n mi southeast of the center of the Strait of Bonifacio and 15 n mi (direct line) northwest of the Gulf of Aranci (Figure 3-2). Winds and resulting wave conditions are strongly influenced by local effects and are not representative of the open sea conditions.

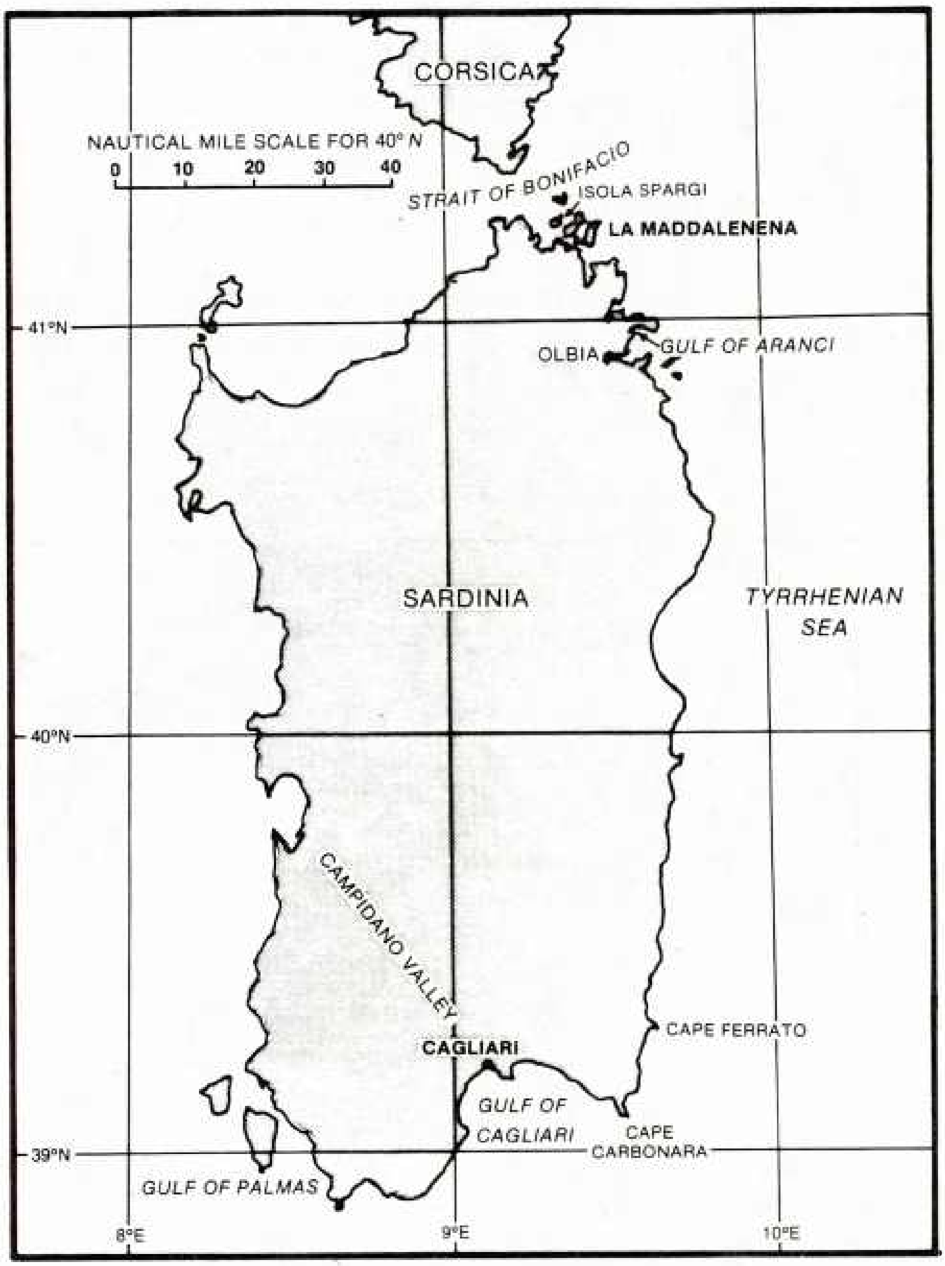

Figure 3-2. La Maddalena Island Complex

3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Figures and Tables are repeated with a continuation of numbering. Paragraph 3.5 provides a general discussion of hazards and Table 3-5 provides a summary of hazards and actions by season.

3.1 Geographic Location

The La Maddalena Island Group is centered near 41.2°N, 9.4°E off the northeast end of Sardinia. It is about 210 n mi west of the Port of Gaeta, Italy (Figure 3-1).

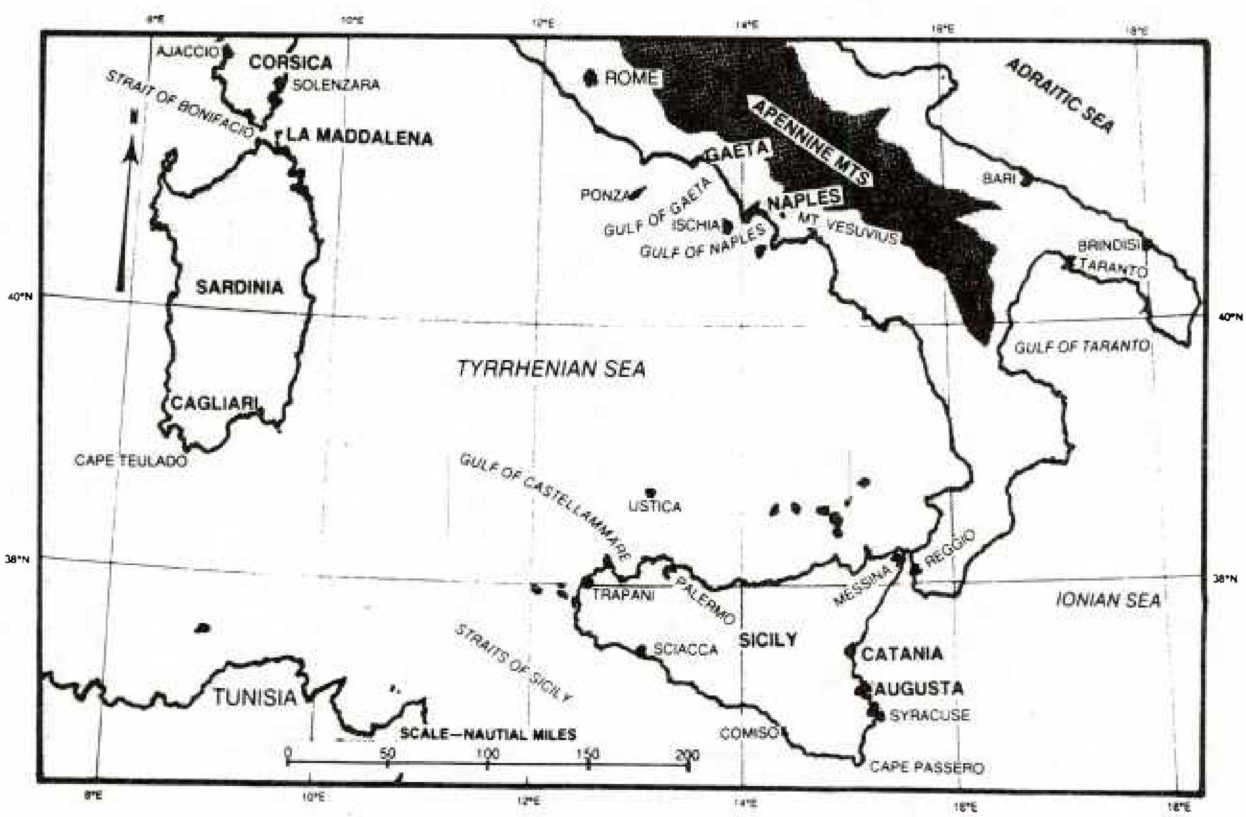

Figure 3-1. Ports of Italy, Sicily, and Sardinia.

The U.S. Navy complex collectively referred to as "La Maddalena" is composed of various sites. A submarine tender has an assigned mooring on the south side of the NATO pier one-third of the way southward along the east coast of Isola Santo Stefano (Figure 3-3). The tender is usually "Med-moored," bow east, stern to the shore with submarines on either side. There is also a fuel pier near the northeast corner of Isola Santo Stefano which is occasionally used by U.S. Navy ships (U.S. Naval Oceanography Command Center, Rota, Spain, 1985).

The Naval Supply Office (NAVSUPPO) La Maddalena is located on Isola La Maddalena about 2,189 yds (2,000 m) north-northeast of the NATO pier on Isola Santo Stefano. The Fleet Landing on Isola La Maddalena is located opposite the northeast corner of Isola Chiesa (U.S. Naval Oceanography Command Center, Rota, Spain, 1985).

An additional site of interest in this study is the Palau city pier located on the north coast of Sardinia. It is used by small boats making frequent runs to/from the submarine tender at the NATO pier and the Fleet Landing on Isola La Maddalena.

Isola La Maddalena is the largest of the islands of the La Maddalena Archipelago. The topography of the region is rugged, with towering granite masses, coves, and gulfs common throughout. Because of the topography, local effects dominate the region's weather and conditions will vary significantly over short distances.

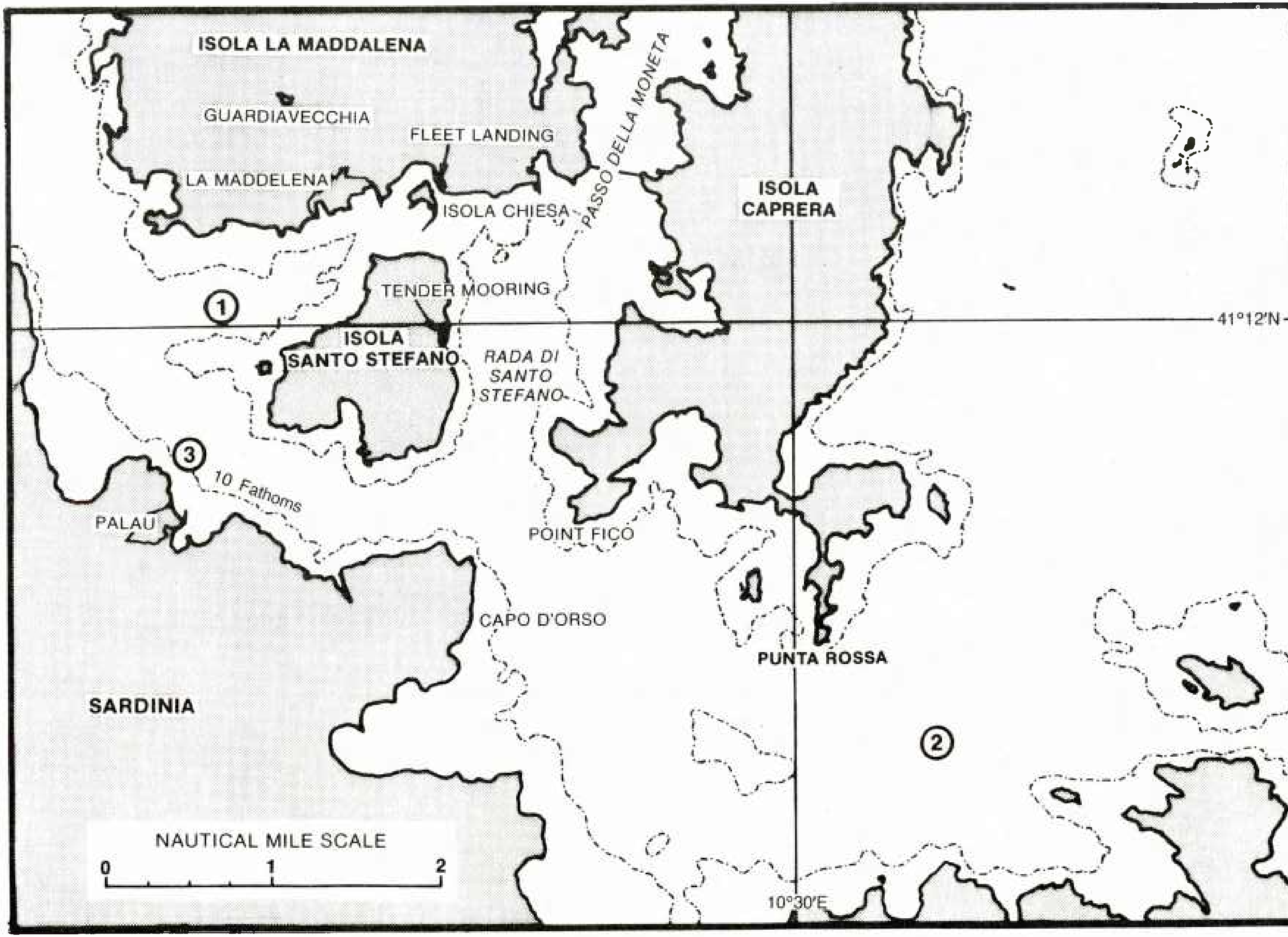

Figure 3-3. La Maddalena Port Complex

3.2 Qualitative Evaluation of the Facilities at La Maddalena

When the submarine tender is in its customary Med-moored position, it is most vulnerable to northeasterly winds which funnel through Passo della Moneta (Moneta Pass) between Isola La Maddalena and Isola Caprera (Figure 3-3). The main weather situation affecting vessels approaching the NATO pier is west or northwest winds called "Ponente". Ponente winds usually result from a "Mistral," with winds turning to westerly through the Strait of Bonifacio (Figure 3-2). During a strong Ponente, it is suggested that vessels anchor in the Gulf of Aranci (near Olbia on the northeast coast of Sardinia) and wait for subsiding conditions. The Gulf of Aranci is well protected from northwesterly winds.

The Fleet Landing on La Maddalena is protected from the effects of northerly winds by the topography of Isola La Maddalena, while the Palau city pier is protected from southerly winds by the topography of Sardinia.

Anchorages in nearby waters are limited due to the presence of submarine cables, but the waters south of the town of La Maddalena are said to offer an anchorage on a bottom with good holding qualities. Regarding anchorage in Rada di Santo Stefano, Volume II of the Mediterranean Pilot, states that "Anchorage can be obtained by large vessels, in depths of from 18 to 23 fathoms (32m to 42m), sand and weed, but the holding ground is not good, and strong westerly winds sometimes cause vessels to drag. The anchorage is secure during northeasterly and southeasterly winds." A number of mooring buoys, for use by Italian naval vessels, are positioned just east of the NATO pier. U.S. Navy aircraft carriers and other large vessels anchor southeast of Isola Caprera.

3.3 Currents and Tides

Currents in Rada di Santo Stefano are generally weak, with the current between the NATO pier on Isola Santo Stefano and Isola La Maddalena having a southeasterly set. Persistent strong winds do influence currents in the area however. A strong Mistral can cause a 3.5 to 4 kt easterly flowing current in the Strait of Bonifacio.

The tidal range in the region is slight, with a spring rise of only about 15 inches.

3.4 Visibility

Visibility is generally good throughout the region, with fog being recorded about once per year.

3.5 Hazardous Conditions

Although the U.S. Naval facilities on Isola Santo Stefano, Isola La Maddalena and Sardinia are well protected from some hazardous wind and wave conditions, they are exposed to others. It is important to note that, according to local mariners, THE PREVAILING WIND DIRECTION AT SEA CANNOT BE ASSUMED TO REPRESENT THAT WHICH WILL BE ENCOUNTERED IN THE LA MADDALENA ISLAND GROUP. The mooring or berthing of the submarine tender is difficult because of the uncertain wind direction. It has become common practice to use smoke flares during berthing operations in order to determine wind direction. A seasonal summary of the known environmental hazards that may be encountered in the area follows.

A. Winter (November through February

The winter season brings cool temperatures, frequent precipitation, and intermittently strong prevailing northeasterly winds to the La Maddalena area.

A significant winter weather problem for the Med-moored submarine tender and tended submarines near the

NATO pier on Isola Santo Stefano is caused by strong northeasterly winds and seas funneled between Isola La Maddalena and Isola Caprera. Most often caused by the development of a Genoa low moving southeasterly across the Tyrrhenian Sea, the winds and resultant seas are broadside to the tender, causing sea water to lap over the hulls of exposed submarines and enter open access hatches. Consequently, submarines tend to nest on the south side of the tender in the lee of the tender's hull. Northeasterly winds do not significantly affect Palau or La Maddalena.

Winter also brings west to northwesterly "Ponente" winds to the region. Ponente winds generally last for 3-6 days, with increasing strength during the first few days, then gradually diminishing. Ponente winds can generate 15-20 ft (4.5 to 6 m) swell in the Strait of Bonifacio, which translate to 8-10 ft (2.5 to 3 m) swell at Palau. Submarines, which normally approach the tender from the southeast, will not come in during a Ponente event. Submarines and other vessels that will not come in during Ponente conditions anchor in the Gulf of Aranci and wait for conditions to subside before entering Rada di Santo Stefano. The Gulf of Aranci is well protected from Ponente winds.

Ponente conditions also adversely affect Navy small boats which normally make hourly runs from the submarine tender to La Maddalena and from the submarine tender to Palau city pier and return. Seas prevent off-loading at Palau because of the danger of crashing against the pier. Normally, in Ponente conditions the boats run only from the submarine tender to/from the Fleet Landing at La Maddalena where personnel can catch a larger commercial ferry to Palau. In <u>high wind</u> conditions the commercial ferry may divert from a direct route to Palau and go around the east side of Isola Santo Stefano to avoid the beam seas from the northwest. In <u>extreme wind</u> conditions, the ferry may stop operation.

Ponente winds are hazardous to helicopter operations in the vicinity of the submarine tender. The

winds create a "swirling" effect, frequently resulting in an eddy over the helicopter pad, which is located just south of the tender on a dock structure.

The La Maddalena region is subject to wind gusts to 30 kt in frontal passages.

The Scirocco, a south to southeasterly wind originating over North Africa, usually occurs during the winter season in the warm sector of cyclones moving across the area (Brody and Nestor, 1980). The impact of Scirocco weather can vary from dust to heavy fog and rain. Although fog is uncommon at La Maddalena, low stratus and fog and restricted visibility are possible in a strong Scirocco event. The rain is often red colored due to dust and sand in the air.

Winter temperatures are moderate, with records of Guardiavecchia (on Isola La Maddalena, 518 ft (158 m) above sea level) showing an extreme winter temperature range of about 30°F (-1°C) to 73°F (23°C) during a 5-year period. While the temperatures do not appear cold by many standards, wind chill (temperature combined with wind) can adversely affect personnel working on weather decks without proper protection. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" and the danger of freezing exposed flesh (adapted from Miller and Thompson, 1970).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
Calm	Calm	50	45	40	35	30	25	20	15	10
		Equivalent Chill Temperature								
3-6	5	48	43	37	32	27	22	16	11	6
7-10	10	40	34	28	22	16	10	4	-2	-9
11-15	15	36	29	22	16	9	2	-5	-11	-18
16-19	20	32	25	18	11	4	-3	-10	-17	-25
20-23	25	30	23	16	8	0	-7	-15	-22	-29
24-28	30	28	21	13	6	-2	-11	-18	-25	-33
29-32	35	27	19	11	4	-4	-12	-20	-27	-35
33-36	40	26	18	10	2	-6	-13	-21	-29	-37

While precipitation in the form of rain/rain showers is common during the winter season, snow is uncommon, having occurred only once in a 15 year period. Hail showers have been recorded at La Maddalena when cloud tops were only 15,000 ft. Thunderstorms occur only about once per year.

B. Spring (March through May)

In the west-central Mediterranean area, the spring season is relatively long and is noted for "periods of stormy weather, with Mistral conditions that alternate with a number of false starts of settled summer-type weather" (Brody and Nestor, 1980). Strongest early in the season, the Mistral brings "Ponente" winds to La Maddalena (See winter season - previous paragraphs).

Low pressure systems continue to develop and move through the Gulf of Genoa and across the Tyrrhenian Sea, bringing strong northeasterly winds to the La Maddalena area and impacting the NATO pier/submarine tender on Isola Santo Stefano. The frequency of occurrence of such storms diminishes as the season progresses, but associated frontal passages can still cause wind gusts to 30 kt in the area.

Temperatures begin to warm, with the mean minimum temperature increasing from about 48°F (9°C) in March to 57°F (14°C) in May. The mean maximum temperatures show a similar trend, increasing from 57°F (14°C) to 67°F (19°C).

Precipitation amounts decrease throughout the season, but a sharp drop is not evident until June. Thunderstorms occur only about once per year.

Visibility restrictions are most common in Spring when compared to other seasons. But observations at Guardiavecchia (altitude 159 m) on Isola La Maddalena for a 5-year period show that visibility reduces to less than 200 m only about one day per year; in general early morning hour visibility is the most restricted.

C. Summer (June through September)

Summer is a season of warm, dry, and relatively settled weather at La Maddalena. The upper-level westerlies and the associated storm track have moved northward. Mistral conditions associated with cold outbreaks are still common near the coast of southern France (Brody and Nestor, 1980), but the effect on La Maddalena is greatly diminished from that experienced during winter and early spring.

Precipitation is at a minimum during June through August, but shows a marked increase in September. Thunderstorms are uncommon, occurring about once per year on average.

As is to be expected, temperatures are the warmest of the year, with a mean minimum of about 68°F (20°C) and mean maximum of 82°F (28°C) in August. Temperatures start to decrease in September.

D. Autumn (October)

The autumn season is short, as the transition from a summer weather regime to winter is abrupt. Mistral conditions cause Ponente winds to come early to La Maddalena, and they can be expected by the end of the

month. Autumn Ponentes are usually not as strong as those of late winter or early spring (See winter, spring sections).

Cyclogenesis increases in frequency as the season progresses, and low pressure systems transit eastward north of Corsica and intensify in the Gulf of Genoa before moving southeastward across the Tyrrhenian Sea. As a result, strong northeasterly winds which funnel between Isola La Maddalena and Isola Caprera start to impact operations at the NATO pier on Isola Santo Stefano. The La Maddalena region is subject to wind gusts to 30 kt in frontal passages.

Temperatures decrease during October, with a mean minimum temperature of about 61°F (16°C) and a mean maximum temperature of about 70°F (21°C) for the month.

Precipitation frequency and amounts increase as the winter season approaches. Thunderstorms occur only about once per year.

E. <u>Tropical Storm Season</u>

Storms having tropical cyclone characteristics with fully developed eyes have been observed on at least three occasions in the Mediterranean basin: 23-26 September 1969, 22-28 January 1982, and 26-30 September 1983. On the latter occasion the storm moved northwest from the Gulf of Gabes (on the southeast coast of Tunisia), through the Straits of Sicily, <u>along the east coast of Sardinia</u>, and into the Gulf of Genoa. Winds of 100 kt were observed near the eye while Cagliari, Sardinia reported winds of 60 kt. The effect at La Maddalena was not reported, but it is likely that northerly winds on the weaker left side of the storm funneled between Isola La Maddalena and Isola Caprera and could have created hazardous wind and wave conditions at the NATO pier on Isola Santo Stefano. The potential for future storms of this type to strike La Maddalena is real and the meteorologist must be aware of the possibility.

3.6 Harbor Protection

While the La Maddalena complex is well protected from some hazardous conditions, it is exposed to others. The following sections address the various conditions and their effect on harbor operations.

3.6.1 Wind and Weather

The NATO pier and the submarine tender on Isola Santo Stefano are protected from winds from 190° to 330° (true). These sites are most vulnerable to northeasterly winds which funnel through Paso della Moneta (Moneta Pass) between Isola La Maddalena and Isola Caprera. Winds from all other directions are diminished by the surrounding topography, with westerly winds of 30 kt often being reduced to 8-15 kt in the NATO pier area. Because of the configuration of the surrounding area, wind directions sometime vary greatly over a short distance. One circumstance testifying to the variability in wind direction occurs on the submarine tender, when the Ensign and Jack of the ship have been known to stand straight out, but in OPPOSITE DIRECTIONS (U.S. Navy, 1979).

Ponente winds are hazardous to vessels at or approaching the NATO pier, as the topography of Isola Santo Stefano causes the strong westerly winds to swirl and eddy. Berthing or mooring evolutions are particularly dangerous when Ponente winds exist.

The Fleet Landing, located on the south side of Isola La Maddalena, is well protected from northerly winds and seas by the topography of the island. It is exposed to southerly winds.

The city pier at Palau, however, is protected by the topography of Sardinia from winds southeast clockwise to northwest, but is open and vulnerable to winds from northwest through east.

The La Maddalena area experiences few winds from east through south.

3.6.2 Waves

While the submarine tender near the NATO pier on Isola Santo Stefano is affected primarily by wind, the submarines it tends are affected mostly by seas. A seemingly insignificant (to most operations) wave motion may cause water to enter the open access hatches of submarines nested alongside the tender.

In a large sample the 5% highest wave heights are at least 2.2 times the significant wave height. If a single 2 ft wave at the tender site was the critical factor, then the critical wind speed/significant wave height values are about 13 kt/0.9 ft over a 3 n mi fetch. These values have about a 95% confidence factor, but users should be aware that there remains a 5% chance of exceeding 2 ft. Therefore, to retain a higher safety factor, it would be prudent to expect an occasional 2 ft wave anytime the sustained wind exceeds about 10 kt for an hour duration over a 3 n mi or more fetch. The tender location is protected from significant wave action by the surrounding islands and has a maximum fetch length of about 3 n mi from the northeast. Fetch length is considerably less in other directions.

The following wind wave forecast aids were derived using the JONSWAP model and the specified critical values. Individual wind waves of 2 ft at the submarine tender site can be hazardous to tendered submarines with open hatches. Based on a maximum fetch of 3 n mi to the north-northeast the following wind speed, significant wave height and 5% highest wave height are provided:

Wind Speed	Significant Wave Height	5% Highest Wave Height
30 kt	2 ft	4.4 ft
16 kt	1 ft	2.2 ft
13 kt	0.9 ft	2.0 ft

The Fleet Landing on Isola La Maddalena is well protected from seas from all directions except south (few high winds from the south), and the fetch is limited to about 6 mi in that direction, between Isola Caprera and Isola Santo Stefano.

The city pier at Palau is well protected from most directions, but is open and vulnerable to sea/swell generated by Ponente winds. A strong event can cause 8-10 ft (2.5 to 3 m) waves at the city pier, posing severe hazards to small boat operations due to the danger of smashing against the pier.

The transit route from the Fleet Landing and/or La Maddalena to Palau is exposed to sea and swell from the northwesterly sector. There is a limited sector of exposed fetch to the west-northwest that extends to the open sea of the western entrance to the Strait of Bonifacio. The distance from mid-channel to the exposed sector of the route is about 13 n mi. The deep water generated swell for point 1 (Table 3-2) indicates that as much as 80% of the swell energy can reach this point for specific swell conditions (300°/12 second deep water swell). Table 3-4 shows that 4 to 6 ft wind waves will be generated by 30-42 kt winds within about 2 hours. Local sources indicate that westerly winds of 15 kt or greater produce 4-6 ft (1.2 to 1.8 m) waves in the passage from the Strait of Bonifacio, south of Isola Spargi, and south of Isola Santo Stefano. Units approaching the northwest roadstead (west of Isola La

Maddalena) from the east can be misled by the calm area in the lee of Caprera, only to be confronted by large swells when entering the Strait of Bonifacio.

Northwesterly winds pose a different problem. Sustained winds of 15 kt or greater create sea and swells in the open area east of Caprera of 10-15 ft (3 to 4.5 m). The area in the vicinity of the tender reflects this condition but does not adequately depict the conditions in the open sea. Also, when outbound through the eastern exit south of Caprera, a calm area sometimes exists east of Capo d'Orso due to the topographical lee of Isola Caprera. This can be misleading as to the sea state existing on the eastern side of Caprera.

Situation specific shallow water wave conditions resulting from deep water propagation are given in Table 3-2. If the actual or forecast deep water wave conditions are known, this table provides the means for determining shallow water wave conditions at the three designated points within the La Maddalena complex area.

> <u>Example: Use of Table 3-2</u>.
>
> For a <u>deep water</u> wave condition of:
>
> 12 feet, 12 seconds, from 300°
>
> The approximate shallow water wave conditions are:
>
> <u>Point 1:</u> 6 feet, 12 seconds, from 245°
> <u>Point 2:</u> protected from westerly swell
> <u>Point 3:</u> 4-5 feet, 12 seconds, from 360°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

LA MADDALENA POINT 1 (West of Isola Santo Stefano).

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	270°	255°	245°	265°	270°	260°
	.1	.1	.1	.2	.2	.2
270°	270°	260°	250°	260°	265°	270°
	.3	.3	.2	.2	.2	.2
300°	275°	255°	250°	245°	240°	240°
	.4	.4	.4	.5	.4	.3
330°	275°	275°	275°	270°	265°	250°
	.4	.4	.3	.3	.3	.3

LA MADDALENA POINT 2 (Southeast of Isola Caprera):

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	010°	010°	010°	010°	020°	020°
	.3	.6	.5	.5	.4	.3
030°	030°	040°	045°	025°	025°	045°
	.5	.5	.5	.4	.4	.3
060°	050°	050°	040°	040°	030°	030°
	.3	.2	.4	.5	.4	.2
090°	045°	045°	040°	040°	040°	040°
	.2	.2	.3	.3	.3	.2
120°	045°	045°	040°	040°	040°	040°
	.1	.1	.2	.2	.2	.1

LA MADDALENA POINT 3 (off Palau City pier):

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
240°	340°	345°	355°	360°	360°	010°
	.1	.1	.1	.1	.1	.1
270°	340°	345°	355°	360°	360°	010°
	.3	.3	.3	.3	.3	.1
300°	340°	345°	355°	360°	360°	010°
	.4	.4	.3	.4	.3	.3
330°	335°	345°	350°	355°	360°	010°
	.2	.2	.2	.2	.2	.2

The seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. This table provides a means of estimating the duration of an existing or forecast wave condition as determined from Table 3-2.

The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Example: Use of Tables 3-2 and 3-3.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:

9 feet, 8 seconds, from 300°

Expected shallow water conditions and duration:

	Point 1	Point 2	Point 3
height	4 feet	Protected	4 feet
period	8 seconds	from	8 seconds
direction	from 255°	300°	from 345°
duration	18 hours	swell	15 hours

Possible applications to small boat operations are selection of the mother ship's anchorage point and/or areas of small boat work. Duration information provides insight as to how long before a change can be expected. The local wave direction information could be of use in selecting anchorage configuration and related small boat operations.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

LA MADDALENA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	21	12	18	18
Average Duration (hrs)	18	14	20	19
Period Max Energy (sec)	10	9	9-10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	3	1	1	2
Average Duration (hrs)	14	18	18	21
Period Max Energy (sec)	12	12	12	12

LA MADDALENA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	2	2	4
Average Duration (hrs)	21	6	8	10
Period Max Energy (sec)	9	9-11	9-10	9-10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	1	<1	0
Average Duration (hrs)	10	6	6	NA
Period Max Energy (sec)	10-11	10	11	NA

LA MADDALENA POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	15	7	11	14
Average Duration (hrs)	15	13	15	19
Period Max Energy (sec)	11	10	10	10-11
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	1	1	1
Average Duration (hrs)	13	9	19	10
Period Max Energy (sec)	12	12	12	12

Local wind wave conditions for selected areas of the La Maddalena complex are given in Table 3-4. The time to reach fetch limited height is based on an initial flat ocean. The time will be shorter with a pre-existing wave.

Table 3-4. La Maddalena. Local wind waves for fetch limited conditions near the submarine tender site (3 n mi fetch), along the ferry route from the Fleet Landing to Palau (13 n mi fetch), and south of Isola Santo Stefano (5 n mi fetch) (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
NNE 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
WNW 13 n mi	2-3/4 2	3-4/4 2-3	4/4-5 2	5/5 2	6/5 2
W 5 n mi	<2 ft	2/3 1	2-3/3-4 1	3/3-4 1	3-4/3-4 1

Example: Small boat wave forecasts (based on the assumption that swell is not a limiting condition).

Forecast for Tomorrow:

Time	Wind (Forecast)	Waves (Table 3-4)
0700 to 1200	WNW 8-10 kt	< 2 ft
1200 to 1500	WNW 22-26 kt	3-4 ft at 4 sec by 1400-1500
1500 to 2000	WNW 34-38 kt	5 ft at 5 sec by 1700
2000 to 2200	WNW 22-26 kt	4 ft or less at 4 sec by 2100

Interpretation: Assuming that the limiting factor is waves greater than 4 feet, small boat operations would become marginal by 1400 and restricted from about 1600 to 2100. Marginal conditions would exist until 2200.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined height is only 1.4 times the common height. In cases where one of the heights is twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave data uses and considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and therefore length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves being characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond in different motions to the different wave lengths present. The information on wave periods, provided in various tables, should be considered when forecasts are made for joint operations of various length vessels.

3.7 Protective and Mitigating Measures

3.7.1 Moving to a more protected location

Northeasterly winds at the NATO pier are the most bothersome and potentially dangerous since the flow is perpendicular to the tender's normal east/west Med-moored configuration. Nevertheless, historically, such winds have never forced the submarine tender to leave the NATO pier. If such a sortie were advised, the bay area southeast of Point Fico (southwest part of Isola Caprera) is considered to be a protected position for anchorage. (NOTE: There may be restrictions to anchoring in this area). Another anchorage considered to be well protected, and one frequently used by vessels waiting for Ponente conditions to abate before approaching the NATO pier, is in the Gulf of Aranci located on the northeast coast of Sardinia near Olbia.

3.7.2 Tending in lee of submarine tender's hull

The favored and recommended location for submarines nested alongside the tender is on the south side due to the vulnerability of the boats to the effects of seas generated by northeasterly winds.

3.8 Local Indicators of Hazardous Weather Conditions

The two conditions which pose the greatest hazards for operations in the La Maddalena complex are northeasterly winds and west to northwesterly Ponente conditions created by Mistral winds blowing through the Strait of Bonifacio.

Northeasterly Wind/Waves - Primarily a late autumn, winter and early spring event, most northeasterly winds at La Maddalena are caused by strong or intensifying extratropical low pressure systems moving from the Gulf of Genoa ("Genoa lows") southeastward

across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southward. It should be noted that a northwest wind can veer to northeast in 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the prevailing pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. Northeasterly winds normally last for 24 to 36 hours after onset.

Westerly (Ponente) Winds/Waves - Strongest in winter and spring, Ponente winds result from a Mistral with winds turning to westerly through the Strait of Bonifacio. A precursor of a forthcoming Ponente is dark stratocumulus clouds building over the west coast of Corsica when clear conditions exist at La Maddalena. Such conditions provide about a 24 hour advance warning of Ponente winds. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule.

When a westerly wind begins to veer to the north, the wind and seas will normally calm in the roadstead in approximately 6-10 hours.

General - When the wind calms, the wave conditions in the roadstead abate rapidly but remain for an extended period of time in the approaches to the roadstead.

TABLE 3-5. Potential problem situations at Port of La Maddalena - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Submarine tender Med-moored at NATO pier on Isola Santo Stefano - Submarines and/or other vessels nested alongside. Late Autumn Winter Early Spring	a. Strong northeasterly winds/seas - Prevailing winter winds are NE'ly at La Maddalena, but a steepened pressure gradient caused by transient low pressure systems moving into/across the Tyrrhenian Sea results in strong northeasterly flow being funneled between Isola La Maddalena and Isola Caprera to the location of the Med-moored submarine tender on east side of Isola Santo Stefano. The enhanced winds and resultant seas cause difficulty at the tender, primarily due to waves washing over the low profile submarines and entering their hulls through open access hatches.	a. Remain at mooring. Tended vessels should be nested in lee of tender. Secure loose gear. Close all submarine hatches that are not required to remain open.	a. Most strong northeasterly winds at La Maddalena are caused by a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southeastward. It should be noted that northwesterly winds can veer to northeasterly within 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. As a rule of thumb, strong northeasterly winds generally last 24-36 hours from onset.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. Ponente winds - A strong west to northwest wind through the strait of Bonifacio and La Maddelena area resulting from a Mistral. Strongest in winter and spring, the Ponente creates variable, swirling winds at the NATO pier site. Ponente conditions make nesting evolutions difficult due to uncertain wind direction and variable wind speeds.	b. Remain at mooring. Double lines as necessary.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Winter Spring Summer Likely Autumn	c. Tropical cyclone - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	c. Because of the potential for destruction, mariners should make every effort to avoid being placed in the path of a tropical cyclone. If at all possible, vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close to La Maddalena.	c. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection of a developing tropical cyclone. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.

TABLE 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. Anchored in Rada di Santo Stefano. Late Autumn Winter Early Spring	a. Strong northeasterly winds/seas - Prevailing winter winds are NE'ly at La Maddalena, but a steepened pressure gradient caused by transient low pressure systems moving into/across the Tyrrhenian Sea results in strong northeasterly flow being funneled between Isola La Maddalena and Isola Caprera to the anchorage in Rada di Santo Stefano.	a. Light to moderate winds (to 25 kt) should pose minimal problems, but vessels should deploy two anchors or consider leaving the anchorage if strong winds are forecast. A more protected anchorage can be found southeast of Point Fico (on Isola Caprera). Secure loose gear. Minimize personnel exposure on weather decks.	a. Most strong northeasterly winds at La Maddalena are caused by a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southeastward. It should be noted that northwesterly winds can veer to northeasterly within 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. As a rule of thumb, strong northeasterly winds generally last 24-36 hours from onset.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. Ponente winds - A strong west to northwest wind through the strait of Bonifacio and La Maddelena area resulting from a Mistral. Strongest in winter and spring, the Ponente creates variable, swirling winds at the NATO pier site. Ponente conditions make nesting evolutions difficult due to uncertain wind direction and variable wind speeds.	b. Remain at anchorage, deploying two anchors if strong Ponente conditions are forecast. Secure loose gear. Minimize personnel exposure on weather decks.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Winter Summer Spring Likely Autumn	c. Tropical cyclone - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	c. Because of the potential for destruction, mariners should make every effort to avoid being placed in the path of a tropical cyclone. If at all possible, vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close to La Maddalena.	c. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection of a developing tropical cyclone. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.
3. Anchored southeast of Isola Caprera. Late Autumn Winter Early Spring	a. Strong northeasterly winds/waves - Some protection can be found to the southeast of Isola Caprera from the high waves. For protection from winds vessels must move westward to south of Isola Caprera.	a. THE PREVAILING WIND AT SEA CANNOT BE ASSUMED TO BE REPRESENTATIVE OF WINDS THAT WILL BE EXPERIENCED IN THE LA MADDALENA ISLAND GROUP. Additional protection from high waves can be found by moving westward toward Capo D'Orso or southeastward to the Gulf of Aranci. Moving westward will provide only limited protection from strong winds. Strong northeast winds can result in anchor dragging throughout the area from southeast of Isola Caprera to the Rada di Santo Stefano.	a. Most strong northeasterly winds/waves in the La Maddalena area result from a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. During such an event the direction will start as northwest and veer to northeast as the low moves southeastward. Note that northwest winds typically shift to northeast within 24 hours and that the northeast flow will continue for 24-36 hours.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. Ponente winds - Wind waves developing over the fetch from near Palau to southeast of Isola Caprera can cause problems for submarines and small craft inbound to Rada di Santo Stefano. To escape strongest winds vessels should move to the Gulf of Aranci on NE coast of Sardinia.	b. Strong Ponente conditions make it advisable to depart the anchorage and move to a more protected location in the Gulf of Aranci on the northeast coast of Sardinia.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Winter Summer Spring Likely Autumn	c. Tropical cyclone - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	c. Because of the potential for destruction, mariners should make every effort to avoid being placed in the path of a tropical cyclone. If at all possible, vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close to La Maddalena.	c. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection of a developing tropical cyclone. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.

TABLE 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4. <u>Arriving/departing La Maddalena Island group.</u> Late Autumn Winter Early Spring	a. <u>Strong northeasterly winds/seas</u> - Prevailing winter winds are NE'ly at La Maddalena, but a steepened pressure gradient caused by transient low pressure systems moving into/across the Tyrrhenian Sea results in strong northeasterly flow being funneled between Isola La Maddalena and Isola Caprera to the location of the NATO pier and Med-moored submarine tender on the east side of Isola Santo Stefano. The enhanced winds and resultant seas make mooring and nesting operations difficult at the NATO pier site.	a. <u>THE PREVAILING WIND AT SEA CANNOT BE ASSUMED TO BE REPRESENTATIVE OF WINDS THAT WILL BE EXPERIENCED IN THE LA MADDALENA ISLAND GROUP.</u> Inbound vessels intending to moor at the NATO pier or submarine tender should remain at sea until the strong northeasterly winds subside. Vessels intending to anchor in Rada di Santo Stefano can proceed to the anchorage, deploying two anchors if conditions warrant. A <u>strong</u> northeasterly wind may preclude anchoring until winds abate. Outbound vessels will have to determine the advisability of getting underway on an as-occurring basis.	a. Most strong northeasterly winds at La Maddalena are caused by a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southeastward. It should be noted that northwesterly winds can veer to northeasterly within 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. As a rule of thumb, strong northeasterly winds generally last 24-36 hours from onset.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. <u>Ponente winds</u> - A strong west to northwest wind through the strait of Bonefacio and La Maddalena area resulting from a Mistral. Strongest in winter and spring, the Ponente creates variable, swirling winds at the NATO pier site. Ponente conditions make mooring difficult due to uncertain wind direction.	b. <u>THE PREVAILING WIND AT SEA CANNOT BE ASSUMED TO BE REPRESENTATIVE OF WINDS THAT WILL BE EXPERIENCED IN THE LA MADDALENA ISLAND GROUP.</u> Due to the uncertain wind direction at NATO pier location and associated mooring/nesting difficulties experienced during Ponente conditions, vessels are advised to delay arrival/departure times until after the winds abate.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Late Autumn Winter Early Spring Weak Summer	c. <u>Northwesterly swell</u> - Mistral and associated Ponente winds result in a northwesterly swell which may reach 15-20 ft (4.5 to 6 m) in the Strait of Bonifacio. The swell is 8-10 ft (2.5 to 3 m) by the time it reaches Palau. Wind waves will develop with strong westerly flow over the fetch south of Isola Santa Stefano and Isola Caprera making it difficult for submarines, which normally approach Rada di Santo Stefano from the southeast, to enter.	c. Since most vessels approach/depart Rada di Santo Stefano from/to the southeast, they will have to transit the exposed waters south of Isola Caprera. Outbound vessels will have following seas and should experience minimal problems. Head seas will be encountered by incoming vessels and may be a problem for submarines and smaller surface vessels. Remaining at sea in the lee of Sardinia or anchoring in the Gulf of Aranci on the northeast coast of Sardinia until the seas abate should be considered.	c. Sea state varies greatly with location due to wind direction and topography. Calm seas in the vicinity of the tender can be misleading under certain conditions to outbound units. (1) Westerly winds of 15 kt or greater will produce 4-6 ft (1.2-1.6 m) or higher swells in the passage from the Strait of Bonifacio, south of Isola Spargi, and west of Isola Santo Stefano. Units approaching from east of Isola Caprera for entrance to La Maddalena from the northwest can be mislead by the calm area in the lee of Caprera, only to be confronted by large waves in the Strait of Bonifacio. (2) Sustained northwesterly winds of 15 kt or greater create sea and swells in the open area of Isola Caprera of from 10 to 15 ft (3 to 4.5 m). The area in the vicinity of the tender reflects this sea condition but does not adequately depict the sea conditions in the open areas. Furthermore, when outbound through the eastern exit south of Caprera, a calm area sometimes exists east of Capo d'Orso due to the topographical lee of Caprera. This can be misleading as to the sea state existing on the east side of Caprera. (3) When the wind at La Maddalena begins to veer to the north, the seas will normally calm in the roadstead in approximately 6 to 10 hours. (4) When the wind calms, the sea conditions in the roadstead abate rapidly but remain for an extended period of time in the approaches to the roadstead.
Winter Summer Spring Likely Autumn	d. <u>Tropical cyclone</u> - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	d. Because of the potential for destruction, mariners should make every effort to avoid being placed in the path of a tropical cyclone. If at all possible, vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close to La Maddalena.	d. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection of a developing tropical cyclone. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.

TABLE 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
5. Small boat operations. Late Autumn Winter Early Spring	a. Strong northeasterly winds/seas - Prevailing winter winds are NE'ly at La Maddalena, but a steepened pressure gradient caused by transient low pressure systems moving into/across the Tyrrhenian Sea results in strong northeasterly flow being funneled between Isola La Maddalena and Isola Caprera to the location of the NATO pier and Med-moored submarine tender on east side of Isola Santo Stefano. The enhanced winds and resultant seas make the operation of small boats at the NATO pier site difficult.	a. Strong northeasterly winds and seas will adversely impact routine small craft operations in the vicinity of the NATO pier but 50 ft boat runs to/from the Fleet Landing at La Maddalena and the Palau city pier normally continue to operate.	a. Most strong northeasterly winds at La Maddalena are caused by a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southeastward. It should be noted that northwesterly winds can veer to northeasterly within 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. As a rule of thumb, strong northeasterly winds generally last 24-36 hours from onset.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. Ponente winds - A strong west to northwest wind through the Strait of Bonifacio and La Maddalena area resulting from a Mistral. Strongest in winter and spring, the Ponente creates variable, swirling winds at the NATO pier site, making small boat operations difficult.	b. Small boat operations are only minimally affected by the Ponente winds directly, buts the seas which may accompany them can cause great difficulty.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Late Autumn Winter Early Spring Weak Summer	c. Northwesterly swell - Mistral and associated Ponente winds result in a northwesterly swell which may reach 15-20 ft (4.5 to 6 m) in the Strait of Bonifacio, but is reduced to 8-10 ft (2.5 to 3 m) by the time it reaches Palau. The swell creates dangerous docking conditions for small boats at the Palau city pier. Heavy sea/swell conditions enroute may cause delay or cancellation of routine boat runs between Palau and La Maddalena. Small boat traffic over routes south and west of Isola Santa Stefano will be curtailed.	c. The 50 ft boats which make the frequently scheduled runs to/from La Maddalena, submarine tender, and Palau experience difficulty during docking at the Palau city pier because the swell motion tends to smash the boats against the pier. Normally, during Ponente conditions the small Navy boats operate only between the submarine tender and the La Maddalena Fleet Landing (where wave impact is minimal), and personnel take a larger commercial ferry to Palau.	c. Northwesterly swell results when Mistral winds blow across the western Mediterranean Sea. If the wind continues through the Strait of Bonifacio (Ponente wind) it will continue to reinforce the swell, but once generated, the swell will propagate through the Strait regardless of the wind. The swell which travels through the La Maddalena Island group is roughly one-half as high as that experienced in the Strait. When the wind at La Maddalena starts to veer to the north, the seas will normally calm in the roadstead in approximately 6 to 10 hours.
Winter Summer Spring Likely Autumn	d. Tropical cyclone - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	d. All small boat operations should cease at the approach of the tropical cyclone. Small craft should be hoisted out of the water and secured on deck or, in the case of shore-based boats, well above the high tide line.	d. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection of a developing tropical cyclone. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.

TABLE 3-5. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
6. Helicopter operations at NATO pier. Late Autumn Winter Early Spring	a. Strong northeasterly winds/seas - Prevailing winter winds are NE'ly at La Maddalena, but a steepened pressure gradient caused by transient low pressure systems moving into/across Tyrrhenian Sea results in strong northeasterly flow being funneled between Isola La Maddalena and Isola Caprera to the location of the NATO pier and Med-moored submarine tender on the east side of Isola Santo Stefano. The enhanced winds flowing over the rugged island region can create dangerous low level turbulence.	a. Helicopters should be operated with caution due to atmospheric turbulence induced by strong winds flowing over/ around the surrounding rugged island region.	a. Most strong northeasterly winds at La Maddalena are caused by a strong or intensifying low pressure system moving from the Gulf of Genoa southeastward across the Tyrrhenian Sea. Wind directions during such an event would typically start as westerly, veering to northeasterly as the low moves southeastward. It should be noted that northwesterly winds can veer to northeasterly within 24 hours. Since winter winds are generally northeasterly, the only advance indication of increased wind velocities may be a steepening of the pressure gradient. The meteorologist must monitor synoptic reports carefully and be alert for anomalous pressure tendencies which could signal increased air flow. As a rule of thumb, strong northeasterly winds generally last 24-36 hours from onset.
Strongest Late Winter And Early Spring Weak Summer Autumn	b. Ponente winds - A strong west to northwest wind resulting from a Mistral, a gap wind blowing across the Gulf of Lion and the western Mediterranean Sea before reaching the Strait of Bonifacio and La Maddalena. Strongest in winter and spring, the Ponente creates variable, swirling winds at the tender site. Ponente conditions make helicopter operations hazardous because of an eddy effect over the helicopter landing area adjacent to the NATO pier.	b. The west to northwesterly Ponente winds create hazardous conditions for helicopter operations near the NATO pier. An eddy is frequently found over the helicopter landing area adjacent to the pier, and swirling wind conditions are the rule during a Ponente. Helicopters should be operated with caution.	b. Ponente winds result from a Mistral, with winds turning to westerly through the Strait of Bonifacio. A 24-hour advance warning of a forthcoming Ponente is provided when dark stratocumulus clouds build over the west coast of Corsica when clear conditions exist at La Maddalena. A Ponente may also be indicated whenever fishing boats do not leave port on their normal schedule. A local forecasting rule states that when a westerly wind begins to veer to the north, the wind will normally calm in approximately 6 to 10 hours.
Winter Summer Spring Likely Autumn	c. Tropical cyclone - Uncommon, especially in winter, but at least one has been observed in the Mediterranean in January. High winds and waves possible.	c. All helicopter operations should cease prior to the onset of gale force (≥34 kt) winds, and the helicopters firmly secured and protected.	c. There is little advance indication of the formation of a tropical cyclone in the Mediterranean. Close monitoring of satellite images and synoptic reports is necessary for early detection. An approaching tropical cyclone may be indicated by noting high, thin clouds in cyclonically spiralling, gradually thickening bands, or unexplained long-period swell approaching from the southern semicircle.

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PORT VISIT INFORMATION

JUNE 1985. NEPRF meteorologists R. Fett and R. Picard met with NOCC Rota meteorologist AGCS Pritchard and on-station shipboard personnel to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3) Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

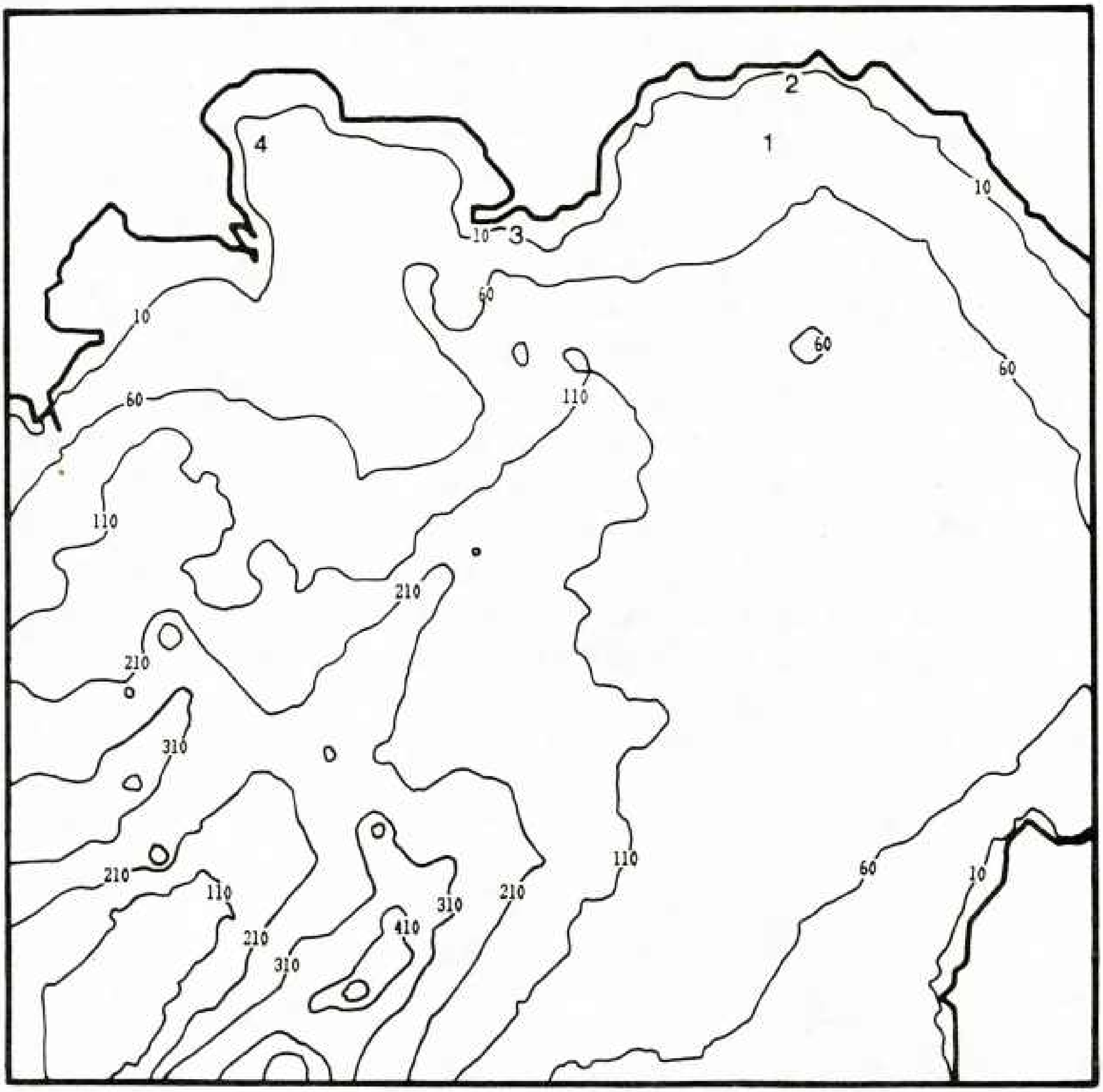

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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